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Manganese

UNITED STATES DEPARTMENT OF THE INTERIOR

The statistical data in this volume represents the most comprehensive, verified, domestic and international coverage for 1987 at the time the volume went to press. More recent information can be found in the monthly Manganese Mineral Industry Surveys obtainable from Publications Distribution, Bureau of Mines, Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236.

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This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Manganese

By Thomas S. Jones[1]

World production of manganese ore declined slightly to the lowest total since 1983, according to preliminary data. Several countries among major market economy country producers had lower outputs, most notably the Republic of South Africa. The United States again produced only a small quantity of manganiferous material for brick coloring.

Price trends in manganese were negative for ores and positive for ferroalloys. Ore delivered to the United States and Japanese consumers was priced about 3% less, so that the U.S. price in 1987 succeeded that in 1986 as the lowest in constant dollars since 1974. In contrast, prices in the United States for imports of key manganese ferroalloys were up significantly to levels last reached in 1982. For U.S. imports, the price rose in 1987 by over one-fifth for high-carbon ferromanganese and about one-third for silicomanganese. One factor cited for higher ferroalloy prices was change in foreign currency exchange rates.

Greater than expected steel production also was considered a factor behind advances in ferroalloy prices. U.S. raw steel production increased 8%, bringing with it an increased consumption of manganese ferroalloys and metal. Unit consumption of these materials in steelmaking was about the same as that of 1986.

U.S. imports declined for all principal forms of manganese, resulting in a decrease of over 12% in overall quantity of manganese imported to nearly the same amounts as in 1984-85. For manganese dioxide the quantity imported was the least since 1981, but that for low-carbon ferromanganese was a record high.

Table 1.—Salient manganese statistics

(Thousand short tons, gross weight)

	1983	1984	1985	1986	1987
United States:					
Manganese ore (35% or more Mn):					
Imports for consumption	966	388	387	488	340
Consumption	531	615	e545	e600	e621
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	34	88	20	14	W
Ferromanganese:					
Production	86	W	W	W	W
Exports	8	7	7	4	3
Imports for consumption	342	409	367	396	368
Consumption	446	492	466	376	409
World: Production of manganese ore	24,147	r28,100	26,742	p26,158	e25,101

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

Manganese was certified by the U.S. Department of State as a strategic mineral essential for the economy or defense of the United States and unavailable in adequate quantities from reliable and secure suppliers. It was therefore unrestricted for importation into the United States from the Republic of South Africa under terms of the Comprehensive Anti-Apartheid Act of 1986. The Government's program of upgrading ore in the National Defense Stockpile into high-carbon ferromanganese was continued through awarding of further contracts for such domestic conversion. Accordingly, the Government inventory of high-carbon ferromanganese was to be increased by 117,000 tons[1] by the end of 1988.

Domestic Data Coverage.—Domestic production data for manganese are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Manganese and Manganiferous Ores" survey. All four operations to which a survey request was sent responded, representing 100% of production.

Legislation and Government Programs.—The General Services Administration contracted further with Elkem Metals Co. to upgrade stockpiled metallurgical manganese ore into high-carbon ferromanganese. This latest award was valued at about $56 million and, in approximate quantities, called for converting 215,000 tons of ore into 117,000 tons of high-carbon ferromanganese, of which 59,000 tons was to have been produced in 1987 and 57,600 tons in 1988. The contract contained an option for additionally converting 103,000 tons of ore into 58,600 tons of high-carbon ferromanganese in 1989.

The only sale of excess stockpile manganese material was in support of the ferroalloys upgrading project, consisting of 2,500 tons of stockpile-grade natural battery ore. Changes in stockpile inventories of manganese materials in 1987 are shown in the following table.

Material	Short tons, gross weight		
	Sales		Change in yearend inventory
	Stockpile grade	Nonstockpile grade	
Natural battery ore	2,500	--	-4,589
Chemical ore	--	--	-232
Metallurgical ore	--	--	-223,109

Table 2.—U.S. Government stockpile goals and yearend inventories for manganese materials in 1987

(Short tons, gross weight)

Material	Stockpile goals	Physical inventory, Dec. 31				
		Uncommitted			Sold, pending shipment	Grand total
		Stockpile grade	Nonstockpile grade	Total		
Natural battery ore	62,000	169,093	33,561	202,654	3,009	205,663
Synthetic manganese dioxide	25,000	3,011	--	3,011	--	3,011
Chemical ore	170,000	171,717	89	171,806	417	172,223
Metallurgical ore	2,700,000	2,078,606	919,204	2,997,810	21,808	3,019,618
High-carbon ferromanganese	439,000	704,952	--	704,952	--	704,952
Medium-carbon ferromanganese	--	29,057	--	29,057	--	29,057
Silicomanganese	--	23,574	--	23,574	--	23,574
Electrolytic metal	--	14,172	--	14,172	--	14,172

On January 7, pursuant to section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, the U.S. Department of State certified manganese to be 1 of 10 strategic minerals essential for the economy or defense of the United States that were unavailable in adequate quantities from reliable and secure suppliers. Manganese was defined in this context to include ferromanganese and silicomanganese. The certification, published on page 4454 of the February 11, 1987, issue of the Federal Register, had the effect of allowing manganese to be imported into the United States from parastatal organizations in the Republic of South Africa.

The U.S. Department of Defense included manganese among 22 high-technology metals and metal groups considered required in future defense systems and having uncertainties as to supply and/or applications. These materials were candidates for increased research and attention. The form of manganese under consideration was high-

purity manganese as electrolytic manganese metal, some of which is used in making superalloys.

The possible benefits of seabed mining in the U.S. Exclusive Economic Zone (EEZ) were studied by the U.S. Congress, Office of Technology Assessment, which concluded that considerably more exploration is required before a definitive assessment can be made. Because of its strategic importance, manganese was regarded as one of several minerals for which national security concerns might override economic considerations in a future decision on whether to engage in extraction from such marine deposits. Otherwise, commercialization of marine minerals within the EEZ was viewed as remote for the foreseeable future except possibly for sand and gravel and precious metals.[3]

DOMESTIC PRODUCTION

Ore and Concentrate.—The only production and shipment of material containing 5% or more manganese was that mined in Cherokee County, SC, by brick manufacturers or contractors for use in coloring brick. This consisted of manganiferous material associated with the Battleground Schist of the Kings Mountain area. This material has a natural manganese content ranging from 5% to 15%. Shipments in 1987 approached the 20,000-ton level that has been generally typical of the 1980's. Consolidation of ownership of the few companies involved precluded publication of proprietary shipments data.

Ferroalloys and Metal.—Publication of statistics continued to be precluded to avoid disclosing proprietary data. There were only two producers each of manganese ferroalloys and metal: Elkem Metals and SKW Alloys Inc. for ferroalloys and Elkem Metals and Kerr-McGee Chemical Corp. for metal.

Chemetals Inc. started a new facility at its Baltimore, MD, plant for producing nitrided ferromanganese and manganese powders. This expansion resulted from relocation and rebuilding of equipment from the Kingwood, WV, plant that Chemetals operated until that plant was disabled by a flood in 1985. Product lines of the new facility included nitrided medium-carbon ferromanganese, nitrided "Massive Manganese," and weld-grade powders of ferromanganese and manganese oxide. These products were in addition to continuing production of various manganese chemicals and ground and reduced manganese ore at the Baltimore plant.

Globe Metallurgical Inc., which had been a producer of silicomanganese in a plant at Beverly, OH, was sold by Moore McCormack Resources Inc. on June 24 to private interests that included members of Globe Metallurgical's management. Moore McCormack had acquired Globe Metallurgical in 1984 through Pickands Mather & Co., then a subsidiary of Moore McCormack.

Table 3.—Domestic producers of manganese products in 1987

Company	Plant location	Products[1]				Type of process
		FeMn	SiMn	Mn	MnO_2	
Chemetals Inc	Baltimore, MD	--	--	--	X	Chemical.
Do	New Johnsonville, TN.	--	--	--	X	Electrolytic.
Elkem Metals Co	Marietta, OH	X	X	X	--	Electric furnace and electrolytic.
Kerr-McGee Chemical Corp	Hamilton, MS	--	--	X	--	Electrolytic.
Do	Henderson, NV	--	--	--	X	Do.
Ralston Purina Co.: Eveready Battery Co.	Marietta, OH	--	--	--	X	Do.
RAYOVAC Corp.: Materials Div.	Covington, TN	--	--	--	X	Do.
SKW Alloys Inc	Calvert City, KY	--	X	--	--	Electric furnace.

[1]FeMn, ferromanganese; SiMn, silicomanganese; Mn, electrolytic manganese metal; MnO_2, synthetic manganese dioxide.

CONSUMPTION, USES, AND STOCKS

Ironmaking and Steelmaking.—The average rate at which manganese was consumed as manganese ore in making pig iron or equivalent hot metal increased to 1.0 pound per ton of raw steel. This rate was calculated from an estimated consumption of 102,000 tons of manganese-bearing ore, all of which contained more than 35% manganese and was of foreign origin. According to preliminary data, production of raw steel as ingots, continuous or pressure-cast blooms, billets, slabs, etc., was 88.5 million tons. No manganese ore containing 35% or more manganese was reported to have been used directly in steelmaking.

Unit manganese consumption in steelmaking as ferroalloys and metal changed insignificantly. For reported consumption in the production of 89.3 million tons of raw steel and steel castings in 1987, the pounds of manganese consumed per ton of raw steel was 7.0 as ferromanganese, 1.6 as silicomanganese, and 0.1 as metal, for a total of 8.7. In 1986, the corresponding unit consumption in production of 82.5 million tons of raw steel and steel castings totaled 8.6, of which ferromanganese accounted for 6.9; silicomanganese, 1.6; and metal, 0.1. The results for both years included less than a full year of steelmaking by USX Corp., which resumed steel production late in the first quarter of 1987. With the nation's largest steelmaking capacity, USX correspondingly had a significant effect on consumption of manganese ferroalloys.

The pattern of manganese ferroalloy consumption by the U.S. steel industry showed a preference for ferromanganese or silicomanganese that depended on type of facilities being used. According to an industry source, integrated producers were obtaining manganese units almost entirely from ferromanganese, particularly the high-carbon grade, whereas the quantity of silicomanganese being used by minimills was over twice that of ferromanganese. To some extent, steelmakers were evaluating use of high-carbon ferromanganese containing 76% manganese, a content less than the traditional 78%, in terms of nominal percentage. A continuing increase in the number of ladle refining units being installed augured for lower unit consumption of manganese ferroalloys in the future because of the high and predictable ferroalloy recoveries associated with use of such equipment. For example, one steel company reported a typical ferromanganese recovery of 98% when practicing ladle metallurgy.

Battery and Miscellaneous Industries.—Dioxide in natural ore and that synthetically produced were being used in dry-cell batteries. Natural material continued to be the basis of carbon-zinc cells and synthetic, the basis of the alkaline-manganese dioxide type. Historical aspects of manganese-containing batteries, particularly those in which synthetic dioxide is used, were reviewed in a publication of The Electrochemical Society.[4]

On June 1, Chemetals acquired the manganese facilities and businesses operated by Foote Mineral Co. in New Johnsonville, TN, thus ending Foote Mineral's role for over 60 years as a domestic supplier of manganese materials. Included in the transaction were a 10,200-ton-per-year electrolytic manganese dioxide (EMD) plant, roasting and grinding facilities for manganese ore, and a marketing arrangement for distributing in the United States electrolytic manganese metal produced in the Republic of South Africa. The purchase price stated when Chemetals and Foote Mineral signed the sales agreement was $12.7 million plus assumption of certain liabilities.

RAYOVAC Corp. realigned its EMD production and ore-grinding plant at Covington, TN, to Materials Div. of the corporation. The plant had formerly been a subsidiary operating as ESB Materials Co.

The ore-grinding activities of N. K. Industries Inc. in Phenix City, AL, were acquired by Prince Manufacturing Co., already a processor of manganese ore in plants at Bowmanstown in eastern Pennsylvania and at Quincy in western Illinois.

Table 4.—U.S. consumption and industry stocks of manganese ore,[1] by use

(Short tons, gross weight)

Use	Consumption		Stocks, Dec. 31	
	1986	1987	1986	1987
Manganese alloys and metal	W	W	197,889	189,444
Pig iron and steel[2]	74,000	102,000	64,800	83,600
Dry cells, chemicals, miscellaneous[3]	W	W	193,544	196,548
Total[2]	500,000	830,000	456,483	469,592

[2]Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Containing 35% or more manganese (natural).
[3]Natural ore, including that consumed in making synthetic manganese dioxide.

Table 5.—U.S. consumption, by end use, and industry stocks of manganese ferroalloys and metal in 1987

(Short tons, gross weight)

End use	Ferromanganese			Silico-manga-nese	Man-ganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	238,522	71,435	309,957	81,812	3,052
Stainless and heat-resisting	16,279	(1)	16,279	5,770	1,505
Full alloy	26,468	9,177	35,645	17,506	975
High-strength, low-alloy	27,025	5,102	32,127	5,310	794
Electric	(1)	(1)	(1)	(1)	(1)
Tool	303	(1)	303	(1)	66
Unspecified	694	802	1,496	416	114
Total steel[2]	309,291	86,516	396,807	108,813	6,506
Cast irons	5,704	635	6,339	2,555	W
Superalloys	W	W	W	W	154
Alloys (excluding alloy steels and superalloys)	W	W	W	W	12,373
Miscellaneous and unspecified	4,658	75	4,733	3,177	536
Total consumption	322,153	87,226	409,879	[3]114,545	25,569
Total manganese content[4]	251,000	70,000	321,000	76,000	25,600
Stocks, Dec. 31: Consumers and producers	37,634	10,429	48,063	13,787	2,988

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified" where applicable.
[1]Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
[2]Includes estimates.
[3]Internal evaluation indicates that silicomanganese consumption is considerably understated.
[4]Estimated based on typical percent manganese content (rounded).

PRICES

Manganese Ore.—Prices depend primarily on manganese content but are also influenced by other factors including other chemical constituents, physical character, quantity, delivery terms, ocean freight rates, insurance, inclusion or exclusion of duties if applicable, buyers' needs, and availability of ores having the specifications desired. Trade journal quotations reflect the editors' evaluation of the market.

Metallurgical manganese ore underwent a price decline on international markets, as did iron ore. Manganese ore contracts negotiated between Japanese ferroalloy producers and Australian and South African suppliers about the April 1 start of the Japanese fiscal year called for a 5.8% price reduction f.o.b. basis. The cost of ocean freight was rising. Thus, reductions on a c.i.f. basis were in the 3% to 4% range. These terms were negotiated for an overall contract volume about one-third less than in fiscal year 1986. In early February, Metal Bulletin of London lowered by 7% its figure for the price of ore delivered to Western European ports. It made no further change but noted in June sluggish demand and delay in settling annual contracts. The price for ore delivered to U.S. customers decreased about 3%, with customers paying some-

what above or below the average depending on volume purchased. The average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was $1.29 per long ton unit, compared with $1.34 in 1986; per metric ton unit, these prices were $1.27 and $1.31, respectively. These prices convert to 5.8 cents and 6.0 cents per pound of manganese in ore, respectively.

Manganese Ferroalloys.—Upward price trends were apparent in the price developments of imported material. The price of imported high-carbon ferromanganese containing 78% manganese, f.o.b. Pittsburgh or Chicago warehouse, began rising in late March from a low reached in the latter part of 1986, ranging from $305 to $320 per long ton of alloy. Frequent incremental increases thereafter led, as of mid-December, to a final price of $380 to $390, the highest range reached since mid-1982. This equated to a price rise of over one-fifth in 1987 and a price average about 7% greater than in 1986. For imported silicomanganese containing 2% carbon, the corresponding increases were relatively greater, a price rise of about one-third in 1987 and a price average over 8% greater than in 1986. Per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, the price of imported silicomanganese started the year at 17 to 18.25 cents, decreased early in January to 17 to 18 cents, and then in mid-February began a succession of changes. All but one were increases, bringing the final price as of mid-December to 22.5 to 24 cents. This final level had not been attained since briefly in January 1982.

Factors cited by trade journals as possibly being behind price rises in manganese ferroalloys were changes in foreign currency exchange rates, greater than expected steel production, uncertainty of supply from the Republic of South Africa, and a desire by producers and marketers to recoup from comparatively low prices in recent years. The extent of increase in the price of imported silicomanganese nearly matched that in the price of imported ferrosilicon. Current list prices of domestic producers for the most widely used manganese ferroalloys were not available in trade publications.

Manganese Metal.—During the first part of the year the list price of domestic suppliers was 80 cents per pound for bulk shipments, f.o.b. shipping point, although a trade journal spoke of transaction prices nearer 78 cents per pound. List prices subsequently were raised twice by 3 cents per pound, first as of August 1 and then as of December 1, to give a yearend price of 86 cents per pound. Timing of the increases was the same for the two domestic producers as well as for Chemetals, a supplier of material imported from the Republic of South Africa.

FOREIGN TRADE

Most of the reported ore exports and all ore reexports were presumed to have been metallurgical ore, and apparently consisted of both stocks from industry and material obtained from excess Government stocks. Of 13,237 tons of reexports, 11,675 tons went to Mexico and 1,562 tons went to Canada. About 1,000 tons of exports apparently was imported manganese dioxide ore, possibly ground, blended, or otherwise classified in the United States, of which about 600 tons went to Canada and the balance to destinations other than Canada and Mexico. Relatively small exports of ferromanganese and silicomanganese were even less than in 1986, by about one-third and two-thirds, respectively. Rising exports of manganese metal were about two-thirds as large as imports.

The overall quantity of manganese contained in the principal forms imported decreased more than 12%, as imports of all major categories declined. Ore imports were down to the range for 1983-85, whereas the average grade for imported ore of 50.1% was the highest yet of the 1980's. Only 5 tons of manganiferous ore was imported, all from Mexico, with an average manganese content of 31%.

The total of ferromanganese imports was slightly less than the average for 1983-86, although imports of low-carbon ferromanganese increased to a record high. The average manganese content of all ferromanganese imports advanced slightly to 78.7%. High-carbon ferromanganese from Japan, in the amount of 5,511 tons, was an unusual receipt for the 1980's. Reported imports of spiegeleisen were 209 tons, all from the Federal Republic of Germany, at a relatively high unit value.

Imports of manganese dioxide decreased for the second consecutive year to the lowest level since 1981. All but 139 tons were apparently synthetic dioxide for battery or chemical applications.

Tariffs.—As of April 1 at U.S. ports open to public navigation, the U.S. Customs Ser-

vice commenced collecting a harbor maintenance fee of 0.04% ad valorem on cargo loaded or unloaded from water-borne vessels. This fee was assessed on import, export, and domestic movements of cargo at all ports at which Federal funds have been used since 1977 for construction, maintenance, or operation, other than inland waterway harbors or channels. The Water Resources Development Act of 1986 (Public Law 99-662) mandated collection of this fee for deposit into the Harbor Maintenance Trust Fund in the U.S. Treasury. Collection of the fee proceeded according to interim regulations (52 FR 10198).

Table 6.—U.S. exports of manganese ore, ferroalloys, and metal, by country

(Gross weight)

Country	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ore and concentrates containing 5% or more manganese:				
Canada	7,669	$613	7,496	$630
Colombia	3,616	295	65	15
Mexico	29,307	2,085	54,284	3,353
Other	1,374	285	815	227
Total[1]	41,966	3,278	63,270	4,225
Ferromanganese:				
Canada	2,433	1,676	1,877	1,351
Germany, Federal Republic of	1,374	554	425	347
Other	[2]616	[2]429	546	447
Total[1]	4,833	2,650	2,851	2,144
Silicomanganese:				
Canada	277	190	249	160
Germany, Federal Republic of	1,189	199	--	--
Mexico	42	54	500	160
Trinidad and Tobago	496	214	4	2
Other	[2]20	[2]30	135	170
Total[1]	2,004	687	697	493
Metal including alloys and waste and scrap:				
Belgium-Luxembourg	702	1,061	701	1,053
Canada	580	1,055	1,208	2,028
Japan	1,705	2,330	1,492	2,606
Netherlands	371	519	706	1,320
Other	[2]1,788	[2]2,927	1,668	2,742
Total[1]	5,146	7,892	5,775	9,749

[1]Data may not add to totals shown because of independent rounding.
[2]Unspecified group of countries; differs from the 1986 Minerals Yearbook.

Source: Bureau of the Census; adjusted by the Bureau of Mines.

Table 7.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and selected chemicals, by country

Country	1986			1987		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
ORE AND CONCENTRATES						
35% or more manganese:						
Australia	68,121	35,539	$3,305	93,206	48,747	$3,819
Belgium-Luxembourg[1]	252	[2]151	27	--	--	--
Brazil	62,702	33,729	3,221	62,908	29,678	2,196
Gabon	229,132	119,069	11,435	175,695	88,413	8,552
Germany, Federal Republic of[1]	5	[2]2	1	--	--	--
Mexico	34,717	[2]14,771	3,003	8,678	3,712	769
Morocco	316	[2]186	36	58	[2]30	14
Panama	6,612	3,174	275	--	--	--
South Africa, Republic of	31,376	13,968	1,219	--	--	--
Total[3]	483,242	225,608	23,122	340,539	170,576	15,079
Of which, more than 35% but less than 47% manganese:						
Brazil	17,492	7,552	541	10,758	4,626	357
Mexico	33,443	[2]14,156	3,391	5,911	2,395	292
South Africa, Republic of	12,044	4,577	430	--	--	--
Total[3]	62,979	26,285	4,362	16,669	7,021	649
FERROMANGANESE						
All grades:						
Australia	13,424	10,401	2,216	8,185	6,072	1,885
Belgium-Luxembourg	4,952	4,465	4,564	2,474	2,150	1,490
Brazil	20,392	15,418	4,945	5,512	4,129	1,400
Canada	52,049	39,907	12,733	24,022	18,861	6,290
France	86,723	65,573	27,546	121,817	96,629	35,426
Germany, Federal Republic of	25,775	21,043	11,181	12,775	10,674	5,947
Italy	--	--	--	412	307	338
Japan	2,908	2,277	1,234	8,231	6,707	2,632
Mexico	28,152	22,540	10,536	17,910	14,562	7,463
Norway	6,663	5,608	4,439	21,830	18,167	12,530
South Africa, Republic of	145,549	113,043	35,944	144,407	112,101	36,180
Spain	9,164	7,775	3,845	--	--	--
Total[3]	395,650	311,045	120,482	367,675	289,379	118,630
Of which, 1% or less carbon:						
Belgium-Luxembourg	4,952	4,465	4,564	522	745	761
France	8,950	8,034	8,180	9,553	8,677	8,965
Germany, Federal Republic of	5	6	8	--	--	--
Italy	--	--	--	412	307	338
Japan	37	34	34	20	18	18
Norway	4,128	3,528	3,633	9,823	8,044	7,122
South Africa, Republic of	54	51	64	--	--	--
Total[3]	18,129	16,178	16,782	20,132	17,852	17,208
More than 1% to 4% or less carbon:						
Belgium-Luxembourg	--	--	--	1,651	1,404	729
Canada	410	315	76	--	--	--
France	2,800	2,226	1,363	6,151	4,997	2,944
Germany, Federal Republic of	25,767	21,037	11,173	12,775	10,674	5,947
Japan	2,766	2,243	1,200	2,800	2,240	1,362
Mexico	20,477	16,572	8,689	15,761	12,884	6,811
Norway	822	709	404	10,743	8,729	5,000
South Africa, Republic of	3,980	3,191	1,633	559	452	250
Spain	9,164	7,775	3,845	--	--	--
Total[3]	66,225	54,068	28,483	50,440	41,359	22,951

See footnotes at end of table.

TABLE 7.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and selected chemicals, by country —Continued

Country	1986			1987		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
SILICOMANGANESE						
Australia	17,262	11,525	$ 5,210	17,142	11,180	$ 4,527
Brazil	19,386	12,880	5,676	7,224	4,676	2,643
Canada	1,822	1,067	320	6,446	4,171	1,969
Chile	176	117	47	--	--	--
Italy	786	473	469	1,105	696	683
Mexico	19,389	12,990	5,649	39,704	24,866	11,072
Netherlands[1]	--	--	--	413	250	251
Norway	16,602	10,917	5,096	28,136	17,159	8,877
Portugal	9,125	5,925	2,755	--	--	--
South Africa, Republic of	83,642	59,114	24,921	66,105	43,736	19,625
Spain	2,694	1,780	1,095	1,962	1,056	1,081
Yugoslavia	22,558	14,777	6,491	25,980	16,525	7,894
Total[2]	198,645	131,435	58,529	191,418	124,315	58,461
METAL						
Unwrought:						
South Africa, Republic of	9,641	XX	9,760	8,925	XX	9,500
Other	27	XX	40	--	XX	--
Total	9,668	XX	9,800	8,925	XX	9,600
Waste and scrap:						
Canada	6	XX	3	60	XX	8
United Kingdom	--	XX	--	6	XX	6
MANGANESE DIOXIDE						
Belgium-Luxembourg	1,975	XX	1,329	1,252	XX	1,508
Brazil	784	XX	845	884	XX	970
Greece	576	XX	645	63	XX	71
Ireland	2,778	XX	3,153	358	XX	401
Japan	10,555	XX	12,440	13,279	XX	14,719
South Africa, Republic of	3,290	XX	3,343	880	XX	889
Other	347	XX	260	150	XX	134
Total[2]	19,374	XX	22,026	16,845	XX	18,692
MANGANESE SULFATE						
Australia	539	XX	123	1,565	XX	289
Belgium-Luxembourg	--	XX	--	127	XX	32
China	--	XX	--	555	XX	95
Germany, Federal Republic of	66	XX	113	80	XX	120
Japan	46	XX	105	27	XX	76
Other	16	XX	34	13	XX	7
Total[2]	658	XX	375	2,317	XX	629
POTASSIUM PERMANGANATE						
China	313	XX	312	908	XX	791
German Democratic Republic	239	XX	290	176	XX	206
Spain	1,298	XX	2,153	918	XX	1,557
Other	16	XX	124	101	XX	290
Total[2]	1,870	XX	2,879	1,998	XX	2,874

XX Not applicable.
[1]Country of transshipment rather than original source.
[2]Includes Bureau of Mines conversion of part of reported data (from apparent MnO_2 content to Mn content).
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census; adjusted by the Bureau of Mines.

Table 8.—U.S. import duties on manganese materials[1]

Item	TSUS No.	Rate of duty effective Jan. 1, 1987	
		Most favored nation (MFN)	Non-MFN
Manganese dioxide	419.4420	4.7% ad valorem[2]	25% ad valorem.
Ore and concentrate	601.27	Free	1 cent per pound Mn.
Ferromanganese:			
Low-carbon	606.26	2.3% ad valorem[3]	22% ad valorem.
Medium-carbon	606.28	1.4% ad valorem[4 5]	6.5% ad valorem.
High-carbon	606.30	1.5% ad valorem[4 5]	10.5% ad valorem.
Silicomanganese	606.44	3.9% ad valorem[2 6]	23% ad valorem.
Metal	632.30	14% ad valorem[5 7]	20% ad valorem.

[1]All subject to ad valorem user fee of 0.22% through Sept. 30, 1987, and 0.17% thereafter, except for products from beneficiary countries under the Carribean Basin Economic Recovery Act (CBERA) and least developed developing countries.
[2]Free from certain countries under Generalized System of Preferences, including Israel.
[3]Not duty free for Mexico.
[4]Free for products of Israel.
[5]Free from beneficiary countries under the CBERA.
[6]Not duty free for Brazil.
[7]5.6% ad valorem for products of Israel.

WORLD REVIEW

Argentina.—A gravity concentration plant for manganese ore was inaugurated in the latter part of the year at Pozo Nuevo, Cordoba Province, in the north-central part of the country. The plant was to be capable of processing about 275 tons per day of low-grade ore containing 12% to 15% manganese from mines in Cordoba and the neighboring Province of Santiago del Estero. This material was to be upgraded into concentrates containing at least 34.5% manganese at a mill recovery of 75%. The product was intended for domestic consumption by the steel industry and others, and would reduce Argentina's dependence on imported ore.

Australia.—Manganese ore production by Groote Eylandt Mining Co. Pty. Ltd. (GEMCO) increased nearly one-eighth to about the same level as in 1984 while GEMCO's exports gained by a slightly greater percentage, according to preliminary data of the Australian Bureau of Mineral Resources. Exports of about 1,440,000 tons plus decreased domestic shipments of about 410,000 tons produced a small advance in total shipments to about 1,850,000 tons.[8]

Programs to increase capacities were completed by this mining subsidiary of The Broken Hill Pty. Co. Ltd. (BHP) and by BHP's manganese smelting subsidiary, Tasmanian Electro Metallurgical Co. Pty. Ltd. (TEMCO). Capacity of GEMCO's ore concentration plant was brought to 2,650,000 tons per year. At TEMCO's plant in Tasmania, rating of two of the three manganese ferroalloy furnaces was raised to 29 megavolt amperes (MVA) and the third to 36 MVA. Because all three furnaces were capable of producing either ferromanganese or silicomanganese, capacity of the plant was upgraded to about 200,000 tons per year for high-carbon ferromanganese or 120,000 tons per year for silicomanganese, or to an intermediate level for a mix of ferromanganese and silicomanganese. TEMCO's ore-sintering capacity was about 275,000 tons per year.

BHP announced through its BHP-Utah Minerals International subsidiary that it planned to build an EMD plant in Australia to be fed with ore from GEMCO. Plant capacity was to be 16,500 tons per year, and production was to begin in 1990. Newcastle, New South Wales, on the southeastern coast north of Sydney subsequently was chosen as the plant site.

Brazil.—Overall shipments of manganese ore from the Serra do Navio, Amapá Territory, operations of Indústria e Comércio de Minérios S.A., all via Porto de Santana on the Amazon River, rose marginally to 807,000 tons. Shipments to Europe rebounded 40% to 430,000 tons. Shipments to other markets decreased, respective quantities being, in tons, to export destinations in North America, 124,000; South America, 39,000; and in coastal vessels to Brazilian consumers, 214,000.[9]

Cia. Vale do Rio Doce (CVRD) shipped a total of 315,000 tons of manganese ore from the Azul Mine in the Carajás region. Shipments were via the Ponta da Madeira iron ore terminal and the commercial dock at

Itaqui, both near São Luís. Exports of 163,000 tons in 11 shipments exceeded somewhat the 152,000 tons making up 14 cargoes sent in coastal vessels to the Brazilian market.[7] Total shipments increased over those of 1986, because exports were nearly one-half greater, whereas domestic shipments declined slightly.

Production of manganese ferroalloys advanced slightly to a new record total of nearly 380,000 tons, according to preliminary data. A drop in production of high-carbon ferromanganese was more than compensated for by increased production of silicomanganese and refined ferromanganese. Problems in such areas as energy cost and supply, labor cost, and Government price control reportedly affected producers at various times during the year.

Diverse proposals for producing manganese ferroalloys in the Carajás region from ore from that region appeared to have culminated in the so-called Provale project. This was a $110 million joint venture in which Brazilian financing was split 60:40 between Prometal Produtos Metalurgicos S.A. and CVRD. The Soviet Union was the third participant in the project through extension of a $60 million credit line to be used for equipment. The Soviet Union was to receive one-half of the projected annual shipments of 165,000 tons of manganese ferroalloys for 12 years beginning with the start of production in 1990.

Gabon.—Compagnie Minière de l'Ogooué S.A. took steps to further manganese ore shipping via the Trans-Gabon Railroad. This included letting contracts for constructing a manganese ore port at Owendo, targeted for completion by the end of 1988, and for installing ore-handling systems to transfer shipments at Moanda from the mine to the railway and at the port from the railway to the ore terminal.

The contribution of manganese ore to Gabon's total export earnings more than doubled in 1986 to over 13% because of a large drop that year in the value of oil exports. In 1984 and 1985, the corresponding contribution had been nearly 6%.

Ghana.—Exports of 269,000 tons of ore from the Nsuta Mine of Ghana National Manganese Corp. were shipped through the Port of Takoradi to the Far East and Europe, western and eastern sectors.[8] This second year of declining shipments brought the annual export total about 8% below that for 1985, the peak year so far in the 1980's.

India.—Hand sorting and picking remained the most common method of beneficiating crushed manganese ore, especially for small mines in remote areas. Ore-washing practices included manual washing in a basket to remove mud as well as mechanical washing at some mines in Madhya Pradesh and Orissa States. Hand or mechanical jigging was the technique most extensively used for gravity concentrating ore. Sandur Manganese and Iron Ores Ltd. practiced jigging plus tabling and low-intensity magnetic separation to treat its ferruginous ore at Sandur in Karnataka State. Manganese Ore India Ltd. remained the only Indian manganese producer having a heavy-medium separation plant. However, this plant, installed over 30 years ago at Dongri-Buzurg Mine in Maharastra State to process ore in dumps, has not been in service for a number of years.[9]

Japan.—Production of manganese ferroalloys decreased about one-sixth to only about 40% of yearend 1986 capacity. Silicomanganese production declined nearly 40% to 101,000 tons. A drop in ferromanganese production to 366,000 tons was not as severe.

Ferromanganese exports of over 21,000 tons were nearly three times as great as in 1986; over 40% of 1987 exports were to the United States. No exports of silicomanganese were reported. Imports of ferromanganese almost quadrupled to 30,200 tons whereas those of silicomanganese declined about 15% to 166,000 tons. The most pronounced changes among sources for silicomanganese imports were increases in quantities from China and the Soviet Union and decreases in those from Brazil and the Republic of South Africa.

The variety of manganese materials being employed in some degree by Japanese steelmakers extended to ferromanganese fines. The effect was to lower consumption of more costly lump ferromanganese, which is also the case with such other recent innovations such as the use of manganese ore in hot-metal pretreatment technology.

In electrolytic materials, production of synthetic manganese dioxide was a near-capacity 73,600 tons and exports rebounded to 48,600 tons. Production and exports of the dioxide were at record highs. Production of 4,050 tons of electrolytic manganese metal was a further decrease from the reduced 1986 output of 4,200 tons.

Mexico.—Cia. Minera Autlán S.A. de C.V. (Autlán) announced in December that

an affiliate, Industrias Sulfamex S.A. de C.V., had completed a plant at Tamos, Veracruz State, with a capacity of 22,000 tons per year for manganese sulfate. Autlán further stated that an EMD plant would be built adjacent to the sulfate plant and would obtain its raw materials from that plant. The EMD plant was projected to have an annual capacity of 13,200 tons and to begin producing in the first half of 1990, largely for export markets.

Norway.—Importing of manganese ore was excluded from economic sanctions against the Republic of South Africa that became effective in July. Under a sanctions program that had been considered for some time, Norwegian ferroalloy producers were allowed to continue importing South African manganese ore for at least 2 more years. In the 1980's, such imports have been the major item in imports by Norway from the Republic of South Africa and were the source of approximately 40% of Norway's manganese feed material in 1986.

South Africa, Republic of.—Following 3 years of progressive increases, ore production decreased over one-fifth to approximately the 1983 level. Production of the various categories of ore was as follows:

	Quantity (thousand short tons, gross weight)
METALLURGICAL ORE	
30% to 40% Mn	734
Over 40% to 45% Mn	852
Over 45% to 48% Mn	483
Over 48% Mn	980
Total	[1]3,050
CHEMICAL ORE	
35% MnO_2 and less	6
Over 35% to 65% MnO_2	129
Over 65% to 75% MnO_2	3
Total	138

[1]Data do not add to total shown because of independent rounding.

Reduced demand in Europe for ore used in making ferromanganese lowered ore sales of The Associated Manganese Mines of South Africa Ltd. nearly 30%, to 968,000 tons compared with about 1,370,000 tons in 1986.

Equipment being installed or tested by Samancor Ltd. to improve its ore production operations included, at the Mamatwan Mine an ore sintering plant and a heavy-medium separation plant and, at the Wessels Mine, a mechanized ore-sorting plant based on the use of X-ray fluorescence. Construction of the commercial-scale sintering plant progressed, whereas the separation and sorting plants were run at pilot scale. Throughout the year, Samancor found it expedient to respond to ferroalloy market changes by shifting production mix back and forth between ferromanganese and silicomanganese at its Metalloys Works at Meyerton in Transvaal Province. The company reacted to a labor protest at the Meyerton plant by discharging over 1,000 workers.

U.S.S.R.—Total concentrate production was unchanged. A slight increase in output from the Nikopol' Basin in the Ukraine compensated for a further decline to 2.8 million tons from the Chiatura Basin in Georgia. This reduced the Chiatura Basin's production to only three-fourths of that region's 1980's peak production of 3.1 million tons in 1984. Considering that the Soviet Union's high-grade concentrates come mainly from the Chiatura Basin, declining production from that region appeared connected both with the Soviet Union's importing of high-grade ore in recent years and its participation in a ferromanganese project in Brazil. A new plant there was to provide the Soviet Union with over 80,000 tons of ferromanganese per year beginning in 1990, according to arrangements previously discussed. (See "Brazil" section of this chapter.)

Ore exports of 1,214,000 tons in 1986 made that the fifth consecutive year in which such exports totaled about 1.2 million tons. Principal destinations for 1986 exports, accounting for 91% of the total, were, in tons, Poland, 637,000; Czechoslovakia, 303,000; German Democratic Republic, 93,000; and Bulgaria, 69,000.

Table 9.—Manganese ore: World production, by country[1]

(Thousand short tons unless otherwise specified)

Country[2]	Range percent Mn[3 2]	Gross weight					Metal content				
		1983	1984	1985	1986[p]	1987[e]	1983	1984	1985	1986[p]	1987[e]
Australia[4]	37-53	1,510	2,038	2,298	1,818	[r]2,043	754	980	1,056	885	974
Brazil[5 7]	30-50	2,306	2,949	2,781	[r e]2,866	2,650	922	1,187	997	1,032	950
Bulgaria	29	50	50	42	[e]44	44	14	14	12	[e]13	13
China[5 6]	30	1,760	1,760	1,760	1,760	1,760	530	530	530	530	530
Gabon[5 8]	50-53	2,047	2,336	2,579	2,707	2,650	945	1,078	1,191	1,277	1,220
Ghana[5]	30-50	191	296	348	375	325	76	116	139	150	130
Hungary[5 10]	30-33	65	74	69	69	71	20	22	21	21	21
India[5 9 11]	10-54	1,412	1,246	1,387	1,337	[r]1,496	530	464	500	502	536
Japan	26-27	83	68	23	7	—	22	18	6	2	—
Mexico	27-50	[e]386	[e]325	[e]437	[e]506	425	147	199	166	192	[e]161
Morocco[5]	50-53	81	65	48	44	47	43	35	26	24	25
Rumania[5 10]	30	86	73	73	[e]72	72	26	22	22	21	21
South Africa, Republic of[5 9]	30-48+	3,181	3,361	3,969	4,100	[r]3,188	1,225	1,341	1,597	1,623	1,310
Thailand[5]	46-50	7	10	5	5	6	4	5	2	2	3
Turkey[5]	27-46	4	47	12	8	8	1	17	4	3	2
U.S.S.R.	29-30	10,890	11,100	10,900	10,900	10,900	3,220	3,300	3,200	3,100	3,100
Yugoslavia	25-45	35	28	[e]28	[e]28	28	12	7	[e]10	[r e]8	8
Other[5 12]	XX	54	[r]61	92	[r]68	51	20	23	[r]28	[r]19	19
Total[13]	XX	24,147	[r]26,100	26,742	26,168	25,101	8,571	[r]9,359	9,516	9,424	9,027

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.

[1]Table includes data available through June 10, 1988.

[2]In addition to the countries listed, Colombia, Cuba, Panama, and Peru may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low-grade ore not included in this table has been reported as follows, in thousand short tons, gross weight: Argentina (19% to 35% Mn), 1983—6, 1984—7, 1985—8, 1986—11, and 1987—11 (estimated); and Czechoslovakia (about 17% Mn), an estimated 1 in each year.

[3]May be for average content of each year's production rather than for content of typical products.

[4]Metallurgical ore.

[5]Reported figure.

[6]Gross weight reported; metal content estimated. Estimated metal content figures have been revised as necessary.

[7]Reported gross-weight figures are the sum of (1) sales of direct-shipping manganese ore and (2) production of beneficiated ore, both as reported in *Anuário Mineral Brasileiro*.

[8]Includes manganiferous ore.

[9]Calculated metal content includes allowance for assumed moisture content.

[10]Concentrate.

[11]Much of India's production grades below 35% Mn; average content was reported as 38.3% Mn in 1983.

[12]Category represents the combined totals of Bolivia (exports), Chile, Greece, Indonesia, Italy (from wastes), the Republic of Korea, Pakistan, the Philippines, and Sudan.

[13]Data may not add to totals shown because of independent rounding.

TECHNOLOGY

The Bureau of Mines performed a laboratory evaluation of a dual leaching method for recovering silver and manganese from refractory domestic manganiferous silver ores. Samples large enough to simulate in situ and/or heap leaching were column-leached in succession. The leaching sequence was relatively dilute aqueous sulfur dioxide (SO_2), an intervening neutralization rinse with sodium hydroxide solution, and finally, caustic cyanide solution. The SO_2 leaching step extracted 65% to 96% of the manganese and 2% to 43% of the silver. Subsequent cyanide leaching brought total silver extraction up to 25% to 82%. Silver extraction was only 0.7% to 8.5% when an SO_2 preleach was not used. The tests were conducted on samples of a hydrothermal vein origin from Arizona, Colorado, and Nevada, in which the manganese content ranged from 2% to 28% and silver content from 1.8 to 7.0 troy ounces per ton.[10]

The Bureau screened sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and acid sulfation processes for extracting cobalt, nickel, and manganese from cobalt-manganese crust ores and concentrates derived from the seabed. All three methods gave extractions of 95% or better for all three metals. Sulfuric acid pressure leaching was regarded the most likely process for this application. Test materials originated mostly from the Necker Ridge and Cross Seamount areas of the Central Pacific Basin in the EEZ.[11] South of Necker Ridge in the EEZ, the Bureau identified a manganese resource potential in crusts in the vicinity of Horizon Guyot and S. P. Lee Guyot of about 20 million and 8 million tons, respectively.[12]

Manganese was one of several strategic and critical metals whose potential recovery from domestic sources by carbonyl processing was investigated in the laboratory by the Bureau. Hydrogen reduction followed by carbonylation at 140° C and 1,500 pounds per square inch carbon monoxide pressure removed most of the iron from a sample of manganiferous ore from Aroostook County, ME, and upgraded the content of such material from 11% Mn, 35% Fe to 20% Mn, 3% Fe.[13]

Calorimetric methods were used by the Bureau in determining thermodynamic properties for pyroxmangite, a Mn-Ca silicate, and fowlerite, a Mn-Zn-Ca silicate.[14]

The Bureau investigated composition and generation rate of fume from shielded metal arc welding with electrode materials typical of those used in mines, with emphasis on the more highly alloyed filler metals. As expected, the data showed manganese in the electrodes to have a relatively high fume propensity. Exposure indices were developed to guide users in selecting electrode materials and avoiding excessive exposure to metals in fume from them.[15]

The Bureau analyzed the role of manganese in the economy of the U.S.S.R., beginning with the origins of the Soviet manganese industry and concluding with the outlook that this industry is likely to experience increased difficulties. Details were presented on reserves, mining, ferroalloy production, technology, trade, and consumption.[16]

Manganese was one of a number of mineral commodities for which the Bureau updated its previous assessment of availability from market economy countries. The indication for manganese continued to be that mine producers active as of 1987 could meet market economy countries' requirements throughout the remainder of the 20th century without expanding capacity, assuming no significant demand increase in the same period.[17]

A classification of the world's principal manganese deposits was put forth from the perspective of a field geologist. The classification was based on the geological environments that gave rise to manganese sediments, the minerals and rock formations associated with them, and secondary deposits formed from the original accumulations.[18]

A computer control system for electric furnaces used to smelt manganese ferroalloys was described. The system was developed by Elkem Metals and commissioned for use at the Bell Bay, Tasmania, plant of TEMCO in 1986 and at the Beauharnois, Canada, plant of Elkem Metals Canada Inc. in 1987. At the latter plant, operation of the system was observed to produce improvements in power level requirements and quality control and cost reductions in electrical energy and labor.[19]

Inclusion of manganese sulfide (MnS) in iron powder metallurgy (PM) mixes improved machinability of PM parts without producing detrimental effects. Tests with a 0.5% MnS addition showed reduced tool friction and wear, thereby leading to longer tool life.[20]

Values were recommended for such thermodynamic properties of manganese metal as heat capacity and enthalpy for the tem-

perature range of 0.5 to 2,400 K and for its vapor pressure from room temperature to 2,400 K, based on a review of data available through March 1985.[21]

Concerns about deleterious environmental effects from mercury in dry-cell batteries have led to efforts to develop schemes for recycling such batteries to recover their manganese, mercury, and zinc contents. Tests of battery recycling and the attendant difficulties were discussed for various hydrometallurgical and/or pyrometallurgical methods. These tests were conducted in Japan, where two plants have begun recovering manganese and zinc from batteries in municipal waste.[22]

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[1]Physical scientist, Branch of Ferrous Metals.

[2]Unless otherwise specified, the unit of weight in this chapter is the short ton (2,000 pounds).

[3]U. S. Congress. Office of Technology Assessment. Marine Minerals: Exploring Our New Ocean Frontier. OTA-O-342, July 1987, 347 pp.

[4]Salkind, A. J. (ed.). Proceedings of the Symposium on History of Battery Technology. Electrochem. Soc., Pennington, NJ (Proc. v. 87-14), 1987, pp. 1-20, 89-105.

[5]Skillings' Mining Review. V. 77, No. 22, June 4, 1988, p. 21.

[6]———. V. 77, No. 20, May 14, 1988, p. 17.

[7]———. V. 77, No. 21, May 21, 1988, p. 10.

[8]———. V. 77, No. 19, May 7, 1988, p. 17.

[9]Bhattacharya, S., and S. Mookherjee. Manganese Beneficiation in India. J. Mines, Metals & Fuels (India), v. 35, No. 4, Apr. 1987, pp. 140-143.

[10]Pahlman, J. E., C. A. Rhoades, and P. G. Chamberlain. Dual Leaching Method for Recovering Silver and Manganese From Domestic Manganiferous Silver Deposits. BuMines RI 9126, 1987, 8 pp.

[11]Allen, J. P., L. J. Froisland, and M. B. Shirts. Chemical Processing of Cobalt-Manganese Crusts. Metall. Soc. AIME tech. paper A87-15, 1987, 18 pp.

[12]Ritchey, J. L. Assessment of Cobalt-Rich Manganese Crust Resources on Horizon and S. P. Lee Guyots, U.S. Exclusive Economic Zone. Mar. Min., v. 07, No. 2, 1987, pp. 231-243.

[13]Vimapatu, A., and L. C. George. Recovery of Critical Metals by Carbonyl Processing. BuMines RI 9067, 1987, 18 pp.

[14]Bennington, K. O., R. R. Brown, H. E. Bell, and R. P. Beyer. Thermodynamic Properties of Two Manganese Silicates, Pyroxmangite and Fowlerite. BuMines RI 9084, 1987, 22 pp.

[15]Mellwain, J. F., and L. A. Neumeier. Fumes From Shielded Metal Arc Welding Electrodes. BuMines RI 9105, 1987, 18 pp.

[16]Strishkov, V. V., and R. M. Levine. The Manganese Industry of the U.S.S.R. BuMines Mineral Issues, 1987, 39 pp.

[17]U.S. Bureau of Mines. Manganese. Ch. in An Appraisal of Minerals Availability for 34 Commodities. B 692, 1987, pp. 177-184.

[18]Machamer, J. R. A Working Classification of Manganese Deposits. Min. Mag., v. 157, No. 4, Oct. 1987, pp. 348-351.

[19]Ray, C. T., and A. H. Olsen. Computer Control of Four Furnaces in Tasmania. Paper in Proceedings of the 45th Electric Furnace Conference (Chicago, IL, Dec. 8-11, 1987). AIME, Warrendale, PA, 1988, pp. 217-223.

[20]Chopra, K. S. Improvement of Machinability in PM Parts Using Manganese Sulfide. Prog. Powder Metall., v. 43, Sept. 1987, pp. 501-510.

[21]Desai, P. D. Thermodynamic Properties of Manganese and Molybdenum. J. Phys. Chem. Ref. Data, v. 16, No. 1, 1987, pp. 91-108 (Note: Only pages 91-97 pertain to manganese).

[22]Nanjo, M. Alkali-Manganese Batteries as New Zinc and Manganese Resources. Paper in Third Battery Material Symposium, ed. by M. Nagayama and A. Kozawa (Honolulu, HI, Oct. 13-16, 1987). International Battery Material Association, Cleveland, OH, 1987, pp. 169-178.

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